SBAS-InSAR SERVICE WITHIN THE G-POD PLATFORM

USER MANUAL

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Contents

Contents ........................................................................................................................................... 2
List of acronyms .................................................................................................................................. 3
Document purpose ................................................................................................................................. 4
Introduction to the SBAS-InSAR processing chain ............................................................................. 5
How to create a SBAS-InSAR task within G-POD platform ................................................................. 6
SBAS-InSAR processing chain steps ................................................................................................... 12
InSAR results available in the Web Portal after processing ................................................................. 14
  Conventions and assumptions ............................................................................................................. 14
  Published Results ............................................................................................................................... 14
Citation and Feedbacks ....................................................................................................................... 17
References ............................................................................................................................................. 18
### List of acronyms

<table>
<thead>
<tr>
<th>ACRONYM</th>
<th>DESCRIPTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>AOI</td>
<td>Area Of Interest</td>
</tr>
<tr>
<td>APS</td>
<td>Atmospheric Phase Screen</td>
</tr>
<tr>
<td>CNR</td>
<td>National Research Council of Italy</td>
</tr>
<tr>
<td>DEM</td>
<td>Digital Elevation Model</td>
</tr>
<tr>
<td>EMCF</td>
<td>Extended Minimum Cost Flow</td>
</tr>
<tr>
<td>ENVISAT</td>
<td>Environment Satellite</td>
</tr>
<tr>
<td>ERS</td>
<td>European Remote Sensing Satellite</td>
</tr>
<tr>
<td>ESA</td>
<td>European Space Agency</td>
</tr>
<tr>
<td>G-POD</td>
<td>Grid Processing On Demand</td>
</tr>
<tr>
<td>GIS</td>
<td>Geographic Information System</td>
</tr>
<tr>
<td>InSAR</td>
<td>Synthetic Aperture Radar Interferometry</td>
</tr>
<tr>
<td>IREA</td>
<td>Institute for the Electromagnetic Sensing of Environment</td>
</tr>
<tr>
<td>MCF</td>
<td>Minimum Cost Flow</td>
</tr>
<tr>
<td>P-SBAS</td>
<td>Parallel Small Baseline Subset</td>
</tr>
<tr>
<td>RSS</td>
<td>Research and Service Support</td>
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<tr>
<td>SBAS</td>
<td>Small Baseline Subset</td>
</tr>
<tr>
<td>SRTM</td>
<td>Shuttle Radar Topography Mission</td>
</tr>
<tr>
<td>SVD</td>
<td>Singular Value Decomposition</td>
</tr>
<tr>
<td>TEP</td>
<td>Thematic Exploitation Platform</td>
</tr>
<tr>
<td>UTM</td>
<td>Universal Transverse Mercator</td>
</tr>
<tr>
<td>VA4</td>
<td>Virtual Archive 4</td>
</tr>
</tbody>
</table>
Document purpose

Purpose of this document is to provide a short user manual for the SBAS-InSAR chain developed on the G-POD infrastructure in order to help the users to properly exploit the service. This manual is addressed to users already familiar with InSAR processing, analysis and products. In addition, specific information on G-POD portal and available functionalities can be found at:

Introduction to the SBAS-InSAR processing chain

Differential Synthetic Aperture Radar Interferometry (InSAR) is a technique for generating displacement maps of single events by calculating the phase difference (interferogram) of two SAR images acquired over the same area and from temporally separated acquisition orbits. By exploiting a large number of differential interferograms, several Advanced InSAR techniques have been developed, allowing to follow the temporal evolution of the ground displacements. From now on we particularly address the Advanced InSAR technique referred to as Small BAaseline Subset (SBAS) algorithm [1].

In the framework of collaboration between CNR-IREA [2] and ESA-RSS [3], the recently developed Parallel-SBAS (P-SBAS) [4] algorithm, which takes benefit from High Performance Computing resources, has been integrated within the ESA’s Grid Processing On Demand (G-POD) [5] environment to provide users with a service for the generation of Earth’s surface deformation time series and, more generally, interferometric products, in unsupervised way. The G-POD flexibility and an user-friendly interface allows users to perform a SBAS-InSAR processing through a distributed computing environments in a reasonable time. The aim of this activity is to provide the Earth Observation community with an automatic tool for improving the surface deformation analyses and thus making advances in understanding several geophysical phenomena.

The SBAS-InSAR chain developed in G-POD platform, up to the present, works on both ERS and ENVISAT data available on Virtual Archive 4, and in the near future will be linked to the ESA Thematic Exploitation Platform (TEP).

The provided service performs the full SBAS-InSAR chain from RAW data (Level 0) focusing to displacement time series generation.

The main user actions are the following:
- select the SAR data to be processed through a defined computing element;
- optionally define the area of SAR data to be processed;
- set input parameters/threshold (e.g. baseline, temporal coherence, ...) for SBAS-InSAR processing;
- follow the processing run step by step;
- obtain SBAS-InSAR geocoded (Lat/Lon and/or UTM WGS84) results, such as mean deformation velocity map and deformation time series.

As additional feature, the possibility to generate single or stack of interferograms co-registered to a single master geometry is also available.
How to create a SBAS-InSAR task within G-POD platform

In this section we describe step by step how to create a task for a full run of the SBAS-InSAR chain.

1. Insert the credentials in the Login field (EO-SSO Login) of G-POD web portal:

   ![Sign In]

2. In the Services List, select the field related to Land Information Services.

   ![Services List]

3. Select the service related to SBAS-InSAR chain algorithm.

   ![SBAS-InSAR]

4. In the **Main Parameters** section the user can:

   ![Main Parameters]

   - **a.** set the **Task Caption**, to univocally identify the task (Default: INSAR SBAS);
   - **b.** select the server on which the final results will be made available to the user (Default: Portal);
   - **c.** set the level of compression of final results (Default: None);
   - **d.** chose the **Computing Element** on which run the processing (Default: ESRIN CE);
   - **e.** set the task priority (Default: Normal).
5. **Select the input dataset for SBAS-InSAR processing.** Note that this step must be carried out with particular care, since a wrong data selection can result to an unfeasible processing. In particular, the user has the following possibility to select data:

   a. Over geographic map select the area of interest (AOI) by properly using the appropriate selection tool:

   The subsequent archive query will return all the data intersecting the selected area. The extension of the AOI could be also defined by inserting the Lower-Left and Upper-Right geographic (lat/lon) corners within the “Geographical selection” box.

   ![Geographical selection](image)

   As a tip, to reduce the amount of data returned by the catalogue query and simplify the data selection, users are suggested to select small areas.

   b. Select the temporal range for catalogue query in the field **Select Date** located over the geographic map.

   ![Select Date](image)

   c. Select SAR archive to be used during query. Available archives are:

   - Virtual Archive 4 (identified by the prefix VA4). Available data are acquired by the ASAR, ERS1 and ERS2 sensors. Note that ERS data are archived with two different tags (IM_ and RAW) within the VA4, so to query the full archive of ERS data we strongly suggest selecting both the available ERS entries.

   - G-POD archive, which contains a subset of the VA4 hosted within the G-POD servers for reducing the data access time.

   The possibility to select data by relative orbit is also provided by inserting the corresponding track number within the **Track Number** field.

   ![Track Number](image)

   d. Thereafter push the button **Query** and the list of retrieved images will be shown.

   e. Select the images that you would process. As mentioned, the input data selection is highly critical and it has to be carefully performed. First of all it is very important that the user select **images related to the same track only**. In case of use of ASAR data, also same sub-swaths have to be considered. A pop-up error message appears in case of simultaneous selection of multiple sub-swaths. Secondly, for ERS data, it is mandatory to **avoid** possible **epoch replications**. Indeed, it is possible that the same area is (partially) covered by two or more frames acquired at the same epoch. For a correct run this data duplication has to be avoided. ASAR data can be selected without caring of this particular constrain since the system automatically discards duplicated images and correctly joins SAR data belonging to different “portions” (frames) of the same strip.

   As selection hint, the user is suggested to first discard the unwanted images, then to select all the remaining data and keep them selected up to the completion of the
task creation. Moreover, when dealing with large selections that span multiple pages, please consider the following hint: select the acquisitions to be processed on the first page, then go to the next page and continue selecting additional files you want to process. In the second page you will see on top the acquisitions already selected on the first page. The same behaviour replicates on the next pages.

6. The **Processing Parameters** field allow user to:
   
a. Set the point used as reference for the displacement measurements generated by the SBAS-InSAR algorithm. It can be set by manually inserting its geographic coordinates in the relevant field:
   
   ![Lat Lon Input Fields]

   The same point can be alternatively set by moving the halo inside the square used for images selection.
   
   In any case, the user shall verify that input coordinates are on land and included within the selected area. As a suggestion, urbanized areas are usually well suitable to locate the reference point.
   
   b. Select the InSAR workflow to be run, in the **Processing Mode** field. In particular, the user can either select:
      
      - **Perform Interferogram Generation**, for generating single interferograms. This workflow terminates at interferograms step and performs the geocoding of each interferogram as well as a corresponding kmz file as a quick-look. Generated interferograms are co-registered with respect to the same master geometry. The minimum required inputs are two SAR data. Up to 7 input acquisition the system compute all possible interferograms respecting the imposed temporal and baseline thresholds. As a hint, to impose the generation of a defined interferogram, a high spatial baseline threshold is needed (being the baseline not a priori known).
      
      - **Perform Multitemporal Analysis**, for generating displacement time series through SBAS-InSAR approach. When selecting this option, the checkbox **Publish Interferograms** is available, to allow user to download the interferograms generated during the SBAS-InSAR processing chain.
      
   ![Publish Interferograms Checkbox]
   
   c. When the checkbox **Cut data over selected AOI** is checked, the system automatically process the AOI identified by the bounding box selection, as performed at point 5a of this User Manual. The area along the SAR strip is selected according to the following Figure.
Acquisitions that do not cover the selected area are automatically discarded. In any case, within this processing mode, the size of the processed area along the azimuth direction ranges between 10000 and 40000 full resolution lines. This feature is available for **ASAR data only** and it is particularly useful for processing the CEOS-DRM data archive.

d. For Expert Users, it is possible to check the **Advanced Configuration** box, which opens a sub-menu containing some input parameters or thresholds that can be set before running the processing. Note that the default values work fine for almost all the ERS and ENVISAT cases.

- **Max Perpendicular Baseline [m]**
- **Max Temporal Baseline [days]**
- **Ground Pixel Dimension [m]**
- **Max Allowed Delta-Doppler [Hz]**
- **Max Allowed Doppler Centroid [Hz]**

In the following a brief description of each parameter is provided:
- **Max Perpendicular Baseline** is the maximum allowed perpendicular baseline between Master and Slave of each exploited InSAR pair;
- **Max Temporal Baseline** is the maximum allowed temporal separation between Master and Slave of each exploited InSAR pair;
- **Ground Pixel Dimension** represents the dimension of the resulting multilooked pixel of the SBAS-InSAR processing. This practically translates
into number of looks along azimuth and range. As an example: 80m corresponds to 20x4 looks in the ENVISAT case, while 40m to 10x2.

- **Max Allowed Delta-Doppler** is the maximum allowed Doppler Centroid difference between Master and Slave of each exploited InSAR pair;
- **Max Allowed Doppler Centroid** represents the maximum allowed Doppler Centroid of each SAR acquisition.
- **Prefer Short Time Interferograms**. If checked, the data pair selection tool prefers short time interferograms. Check it when the temporal decorrelation is high and the critical baseline is large. Note that to keep short time interferograms the perpendicular baseline threshold must be increased.
- **Common Band Filtering** allows performing, if selected, a common band filtering in the interferogram generation.
- **Goldstein Weight** is the exponential value of the Goldstein’s phase filter (0.5 as default value) [6]
- **Coh Threshold** represents the Coherence Threshold on the pixels before unwrapping and can assume values between 0.6 and 1 [8]
- **APS Smoothing Time Window** is the temporal window width (in days) for the APS filter on the resulting time series.

7. Once all the data are selected and parameters and thresholds are set, it is possible to save the project in the workspace by pushing the **Save in Workspace** button. A status message informs the user on the operation conclusion.

8. In the **Workspace** folder the user can find the saved workflows as well as those already generated, active and finished.

9. By selecting the task of interest a new page is opened, showing several information on the created task. More specifically:
   a. Task ID
   b. Service Used
   c. Status of the task
   d. Progress (a progress bar relevant to the whole processing chain)
   e. Creation Time
   f. Submission Time
   g. Completion Time
Moreover, the complete workflow of the SBAS-InSAR chain is also shown. Each step will change colour during the processing, according to the following code:

- Blue: step not yet started;
- Yellow: step running;
- Green: step completed;
- Red: step failed.

Under **Task Operations** section some platform related parameters can be changed: **Priority** of the Task, **Computing Resource** to be used, **Server** where publish results, **Compression** of results, **Task Caption**. Changes have to be applied by clicking the **Modify** button.

Several Task operational functions are available:

a. **Copy**, to copy the Task in the user workspace;
b. **Clone**, readdress the task to the initial page for data selection refining and processing parameters modifications;
c. **Recreate**, to recreate the Task;
d. **Submit/Resubmit**, to submit the created task once all the parameters have been set.
e. **Requery Input Data** box force a new download of input SAR data.
f. **Abort**, to end a running Task;
g. **Delete**, to delete from the workspace a defined Task;
h. **Modify**, to apply changes to a Task.

10. User can check the ongoing processing and the input/output parameters of each processing step through the **Jobs Information** section.
**SBAS-InSAR processing chain steps**

In this section a high level description of the SBAS-InSAR processing chain is provided. References to the used algorithm are also given. Note that the steps up to the **Interf** are in common to both the Interferogram Generation and Multitemporal Analysis Processing Mode.

**Def** This step performs the SAR RAW data extraction and orbit state vector interpolator.

**FocMas** This step computes the parameters relevant to the whole dataset and required for all the functionalities of SBAS elaboration chain, estimates the master image sensor velocity and performs its focusing.

**Foc** In this step the focusing of each SAR data, except for the master image, is carried out. If needed, a scaling is performed to refer all data to the same pulse repetition frequency (PRF) and to the same range sampling frequency.

**CAS** This step performs the Common Area Selection, by estimating the shift at pixel level along azimuth and range directions with respect to the master acquisition of SAR dataset.

**Cut** Taking into account the output of step CAS, areas that are not common to the whole dataset are removed from each image.

**DEM1-2-3** This step converts the SRTM DEM relevant to the zone under study in to the SAR coordinate of the reference master image.

**Range** Taking into account orbital information the Range and Azimuth files are computed.

**Merge1** Merging results step

**Coreg** In this step the images co-registration with respect to the master acquisition is performed, so that all images are referred to a common reference grid. The registration step aligns the SLC images with sub-pixel accuracy [7].

**IntPar** This step performs the interferometric pairs selection according to the spatial and temporal constraints set in the GPOD web portal. In addition several interferometric parameters are computed to be used in subsequent steps.

**Merge2** Merging results step

**RegRef** A further sub-pixel shift calculation is performed by exploiting the spatial coherence between data pairs.

**Merge2** Merging results step.

**Merge3** Merging results step.

**Mas_Reg** Outputs of step RegRef are inverted (LS) for a single master and a subsequent co-registration is performed for each image.

**DEM_Reg** In this step the residual shifts both in azimuth and in range directions between master image and the DEM converted in SAR coordinates are computed.

**Interf** The Interf step generates multilooked differential interferograms both unfiltered and filtered with Goldstein filter [6]. Coherence maps are also provided.

The following steps are relevant to the Multitemporal Analysis only.

**TPHU** Temporal Phase Unwrapping according to the EMCF algorithm [8]

**SPHU** Spatial Phase Unwrapping according to the EMCF algorithm [8]
AddPHU) Phase unwrapping of interferograms not belonging to network needed by the EMCF algorithm is performed via a conventional MCF.

SVD) Singular Value Decomposition (interferograms inversion) according to [1].

OrbRamp) Residual Orbital Ramp estimation and removal

SPHUb) Second round of EMCF Phase Unwrapping on orbit error free interferograms.

AddPHUb) Second round of MCF Phase Unwrapping on orbit error free interferograms not belonging to the EMCF network.

SVDb) Second round of Singular Value Decomposition.

APS) Final processing, Temporal coherence computation, Atmospheric Phase Screen estimation and removal, generation of the output files.
InSAR results available in the Web Portal after processing

The result that the user will find on web portal are strongly depending on the selected **Processing Mode**.

**Conventions and assumptions**

Note that all the published binary files (.dat) are in 32-bit floating point raster format (if not differently specified) without any header information.

The origin of each binary matrix is located in the Lower Left corner.

Results provided in SAR coordinates have the Azimuth direction along the columns (X) and Range direction along the rows (Y).

Results provided in GEO coordinates (Lat-Lon WGS84) have the Longitude direction along the columns (X) and the Latitude direction along the rows (Y).

In the naming convention, the <ddmmyyyy> represents the day, month and year of a specific date while <SSS> is a three character code referring to the used sensor (e.g, ERS, ENV, ...).

**Published Results**

I. For the **Interferogram Generation** Mode a .tgz folder related to each interferogram pair (in the format <ddmmyyyySSS>_<ddmmyyyySSS>.tgz) is published; each folder contains:

- fr.dat: Interferogram as binary file in SAR coordinates;
- coh.dat: Coherence map as binary file in SAR coordinates;
- fr.dat_GOLD: Interferogram filtered with Goldstein kernel as binary file in SAR coordinates;
- fr.dat_GOLD_GEO_<dimLon>x<dimLat>: Geocoded Goldstein filtered interferogram as binary file;
- coh.dat_GEO_<dimLon>x<dimLat>: Geocoded Coherence map as binary file;
- fr.dat_<ddmmyyyySSS>_<ddmmyyyySSS>_GOLD_GEO.tif.kmz: Quick-look of the geocoded Interferogram importable in Google Earth.

II. For **Multitemporal Analysis** Mode a .tgz folder named “result_final” is published, which contains:

- One ASCII file containing all the outputs of the SBAS-InSAR chain processing.

The first record contains, respectively: the number of field of each record; the number of acquisitions used in the time series and the measure unit for the mean displacement velocity.

The second record contains the list of the epochs of acquisitions used in the time series, given as fraction of year.

All the others records contain, per each pixel:

- East and North UTM WGS84 coordinates (in meters);
- Temporal coherence value;
- Mean displacement velocity, calculated as linear fit of the relevant time series (in centimetres per year);
- SAR coordinates (in pixels);
- geographic WGS84 coordinates (latitude and longitude, in degrees);
- residual topography w.r.t. the used DEM (in meters);
- deformation time series (in centimetres).
The basic scheme of the output ASCII file is reported in Figure 1.

The file name is: SBAS_output4GIS_<ddmmyyyySSS>_<ddmmyyyySSS>.txt, where the two date indicate the starting and ending acquisitions used for generating the displacement time series.

- One .kmz file containing the Quick-look of the retrieved mean deformation velocity importable in Google Earth.
Figure 1: Format of the ASCII file, which encloses the outputs of the SBAS-InsSAR processing chain.

<table>
<thead>
<tr>
<th>Year</th>
<th>East Coord. (UTM - WGS84)</th>
<th>North Coord. (UTM - WGS84)</th>
<th>Temporal Interferometric Coherence</th>
<th>Deformation Coords</th>
<th>Topography (m)</th>
<th>Deformation Time Series (cm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1992</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
</tr>
</tbody>
</table>
Citation and Feedbacks

Commercial use of any part of this service is not allowed without express permission from the CNR-IREA Institute and ESA.

Users are encouraged to use the InSAR service here described for any scientific aim. Being this service available for free for scientific use, please recognize the effort made by the authors by citing:


in relevant talks and publications prepared by using InSAR results generated by this service.

Users are also kindly invited to report any issue and problem encountered during the use of this service to eo-gpod@esa.int and sbas-help@irea.cnr.it. Moreover, suggestions and comments are warmly appreciated in order to keep the service as much as possible appealing, effective and efficient.
References


[5] https://gpod.eo.esa.int/

